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(54)Title of the Invention

10 ENCODING METHOD USING LEVEL PLANE DEVELOPING
METHOD AND ENCODING/DECODING APPARATUS

(57)Abstract

[Purpose]

15 The purpose is to optimize a pattern of an inter-level
connection in accordance with predicted properties of an
information source and to encoding even the information source
having all statistic properties at almost fixed efficiency, in an
encoding method and an encoding / decoding apparatus which use a
20 level plane developing method in converting multiple value
information into binary information.

[Construction]

In encoding, a group generation counting device 12
dynamically changes a grouping pattern by which a grouping
25 operating device 11 identifies a number of a group to which
encoded-target data belongs and inter-group position information.

In decoding, de-grouping is performed from the grouping pattern which is obtained similarly by a grouping generation counting device

14.

[CLAIMS]

1. An encoding method using a level plane developing method in converting multiple value information into binary information,
5 characterized in that,

said encoding method comprises:

a process of inputting encoded-target data;

a process of identifying a belonging group and a inter-group
position information in accordance with grouping pattern
10 information of a level plane and outputting a group number and the
inter-group position information;

a process of accumulating a generation count for each group
and calculating generation probability; and

a process of reconstructing the group by dividing or connecting
15 the group on the basis of the generation probability for each group,

a pattern of an inter-level connection being dynamically
change,

an encoding to minimize entropy being performed.

20 2. An encoding apparatus using a level plane developing method
in converting multiple value information into binary information,
characterized in that

said encoding apparatus comprises:

a grouping operating device for inputting encoded-target data
25 and generating a group number indicating which group the
encoded-target data belongs to and a inter-group position

information indicating which position the encoded-target data locates on in accordance with defined grouping pattern information; and

5 a group generation counting device for counting the group number which is generated by said grouping operating device, reconstructing the group such that entropy of encoding is minimized with respect to information source by dividing or connecting the group on the basis of a generation probability of the group which is calculated from a counting result, and informing said grouping
10 operating device about the grouping pattern information of result of the reconstruction.

3. The encoding apparatus according to claim 1, characterized in that

15 said encoding apparatus comprises:

an entropy encoding device for entropy encoding the group number which is generated by said grouping operating device;

an equal length encoding device for equal length encoding the inter-group position information which is generated by said grouping
20 operating device; and

a code combining device for generating coding data by combining an output of said entropy encoding device and an output of said equal length encoding device.

25 4. An decoding apparatus for decoding data which is encoded by using a level plane developing method in converting multiple value

information into binary information, characterized in that

said decoding apparatus comprises:

a de-grouping operating device for inputting a group number and a inter-group position information which are obtained from inputted encoded data, and restoring original data in accordance with grouping pattern information which is defined as same manner in encoding; and

a group generation counting device for counting the group number which is obtained from the inputted encoded data, reconstructing the group such that entropy is minimized with respect to information source by dividing or connecting the group on the basis of the generation probability of a group which is calculated from a counting result, and informing said de-grouping operating device about the grouping pattern information of result of the reconstruction.

5. The decoding apparatus according to claim 4, characterized in that

said encoding apparatus comprises:

an code dividing device for dividing the inputted encoded data into an entropy encoded data portion and an equal length encoded data portion;

an entropy decoding device for restoring the group number from the divided entropy encoded data portion, and outputting the group number to said de-grouping operating device and said grouping generation counting device; and

an equal length decoding device for restoring the inter-group position information from the divided equal length encoded data portion, and outputting the inter-group position information to said de-grouping operating device.

5

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[TECHNICAL FIELD TO WHICH THE INVENTION BELONGS]

The present invention relates to an encoding method and
10 encoding / decoding apparatus using the level plane developing method for encoding while optimizing the plane developing pattern of the level plane developing for converting multiple value information into binary information.

[0002]

15 [Background Art]

An entropy encoding is frequently used as a technology of information source compression. As the entropy encoding, an arithmetic encoding recently attracts an attention. However, in the arithmetic encoding method, it is preferable that information being
20 an encoded target is binary information source. For this reason, in the case of using multiple value information source, the multiple value information source is inputted into the encoding apparatus after it is converted into the binary information source. At this time, a level plane developing method is often used as converting method.
25 However, since information being the encoded target becomes very large, it is inputted into the encoding apparatus after the inter-level

connection is performed and quantity of the level is degenerated (grouping of the level is performed), namely after bit array after converted is reduced.

[0003]

5 Figs. 10 explain an example of inter-level plane connection. Fig. 10(A) shows each level of M value information sources from 0 to $M-1$ on a number line. With respect to this, the inter-level connection is performed by grouping as shown in Fig. 10(B), and thereby the quantity of the level is degenerated. In Fig. 10(B), G_i represents a group number, m_i represents a size of the group and P_i represents a generation probability of each group. if the quantity of the group is n , i is represented by values of one 0 to $n-1$. At the condition after grouping, each level value is represented by the group number and position information of the level value in the group.

10 For example, the level value of $(M-2)$ is represented by $G_{n-1}+(01)_2$, because its group number is G_{n-1} and its position information in the group is $(01)_2$ th position.

[0004]

20 The entropy which the information source has increases (thereby efficiency of the encoding deteriorates) in accordance with the degeneration operation of the quantity of the level. For this reason, it is need to perform the inter-level connection which optimally matches the information source which is encoded target, in order to minimize the increase.

25 [0005]

In the conventional inter-level connection, firstly, a DPCM

(Differential Pulse Code Modulation) is performed with respect to the information source, secondary, a statistic property of the information source is converted (in this case, the property is approximated by Laplace distribution), and thereby the inter-level connection which is optimized for Laplace distribution is performed.

[0006]

This process is used as a SPATIA encoding of JPEG or the like.

[0007]

[PROBLEM TO BE SOLVED BY THE INVENTION]

If the information source being the encoded target is like natural image, its statistic property is almost approximated by Laplace distribution by the DPCM (it is natural that exception occurs). However, if the information source is like texture image, its statistic property cannot be approximated by Laplace distribution by the DPCM.

[0008]

Figs. 11 explain the statistic property of the information source. Fig. 11(A) shows a distribution of the values which are obtained by performing the DPCM with respect to the natural image which is quantized by 8 bits. Fig. 11(B) shows a distribution of the values which are obtained by performing the DPCM with respect to the texture image which is quantized by 8 bits. In the case of the natural image, since there is many portions each in which a change of data value which is the information source is relatively small, the distribution obtained by performing the DPCM is approximated by Laplace distribution as shown in Fig. 11(A). On the other hand, in

the case of the texture image, since the texture image has many monochrome changes and has little intermediate change of brightness, for example, the distribution is absolutely different from Laplace distribution as shown in Fig. 11(B).

5 [0009]

In this case, if the inter-level connection fixed while being optimized with respect to Laplace distribution, the efficiency of the encoding deteriorates when the texture image which has the statistic property of the information source as shown in Fig. 11(B).

10 [0010]

It is an object of the present invention to predict / analogize the property of the information source which is the encoded target, to optimize a pattern of an inter-level connection in accordance with the predicted property, and to encoding even the information source
15 having all statistic properties at almost fixed efficiency.

[0011]

[MEANS FOR SOLVING THE PROBLEM]

Fig. 1 is a principle block diagram of the present invention. In the present invention, a probability distribution of the
20 information source is approximately analogized and a grouping pattern is dynamically updated by dividing / connecting each group, parallel with encoding the information source.

[0012]

As shown in Fig. 1(A), an encoding apparatus of the present
25 invention is provided with a grouping operating device 11 for inputting encoded-target data and generating a group number

indicating which group the encoded-target data belongs to and a inter-group position information indicating which position the encoded-target data locates on in accordance with defined grouping pattern information. Moreover, the encoding apparatus of the present invention is provided with a group generation counting device 12 for counting the group number which is generated by the grouping operating device 11, reconstructing the group such that entropy of encoding is minimized with respect to information source by dividing or connecting the group on the basis of a generation probability of the group which is calculated from a counting result, and informing the grouping operating device 11 about the grouping pattern information of result of the reconstruction.

[0013]

Moreover, as shown in Fig. 11(B), a decoding apparatus of the present invention is provided with a de-grouping operating device 13 for inputting a group number and a inter-group position information which are obtained from inputted encoded data, and restoring original data in accordance with grouping pattern information which is defined as same manner in encoding; and a group generation counting device 14 for counting the group number which is obtained from the inputted encoded data, reconstructing the group such that entropy is minimized with respect to information source by dividing or connecting the group on the basis of the generation probability of a group which is calculated from a counting result, and informing the de-grouping operating device 13 about the grouping pattern information of result of the reconstruction.

[0014]

[EFFECT]

The present invention can change the pattern of the connection dynamically such that the statistic property of the information source which is the encoded target is analogized and the optimum inter-level connection is performed, and minimize the entropy with respect to even information source having all statistic properties, in order to reducing (scale down) a condition after the developing is performed, when the level plane developing which is used in converting the multiple value information into the binary data is performed. For this reason, the present invention counts generation for each group by accumulating the data which is already encoded, calculates the generation probability from the counting result, and reconstructs the dynamic group (i.e. performing the dynamic inter-level plane connection) on the basis of the generation probability.

[0015]

[EXAMPLE]

Fig. 2 is a block diagram of an encoding apparatus in the example of the present invention. Arrows in the drawing indicate flows of the signals.

[0016]

A DPCM device 21 performs a difference encoding with respect to the information source which is the encoded target. However, the DPCM device 21 is not essential. If the DPCM device 21 is eliminated, the encoding apparatus of the present invention can be

constructed.

[0017]

An entropy encoding device 22 performs an entropy encoding the group number which is generated by the grouping operating
5 device 11. Moreover, an equal length encoding device performs an equal length encoding the inter-group position information which is generated by the grouping operating device 11.

[0019]

A code combining device 24 combines encoded data bit series
10 which are outputted from the entropy encoding device 22 and the equal encoding device 23. For example, if the output of the entropy encoding device 22 is "010001" and the output of the equal length 23 is "110", the output of the code combining device 24 is "010001110".

[0020]

15 The output of the code combining device 24 becomes encoded data and is transmitted to a decoding apparatus on receiving side shown in Fig. 3. Fig. 3 is a block diagram of the decoding apparatus in the example of the present invention. Arrows in the drawing indicate flows of signals.

20 [0021]

A code dividing device 31 divides the encoded data which is received into the entropy encoded data portion and the equal length encoded data portion. An entropy decoding device 32 decodes the entropy encoded data and restores the group number. An equal
25 length decoding device 33 decodes the equal length encoded data and restores the inter-group position information.

[0022]

A group generation counting device 14 get a statistics of the group number which is entropy decoded and restore a pattern of the division which is same as a pattern of the division determined on transmitting side. The group generation counting device 14 is same as the group generation device 12 on the encoding apparatus side as shown in Fig. 2.

[0023]

A de-grouping operating device 13 generates the original information source (or difference encoded data) from the equal length code which is obtained by decoding from the equal length decoding device 33 and the group number which is obtained by decoding from the entropy decoding device 32.

[0024]

An inverse DPCM device 34 decodes the difference to thereby generate the original information. As described above, if the DPCM device 21 is eliminated in the encoding apparatus, the inverse DPCM device 34 may be eliminated in the decoding apparatus, too.

[0025]

Incidentally, in the example, following two conditions are applied as necessary condition for dynamic grouping operation.

(1) A total quantity of the group is fixed around (before and after) the change of the group.

(2) The change operation of the group is synchronously performed on the transmitting side and the receiving side (the encoding apparatus and the decoding apparatus) and information for the change is not

transmitted between them.

[0026]

This section (2) means that it is not need to transmit an encoding table between the encoding device and the decoding device.

5 This can be one characteristic of the present method. For example, the case where N numbers of information are already encoded (or decoded) and (N+1)th information is to be encoded (or decoded) from now is explained. If the (N+1)th information belongs to group i and there is M numbers of information out of N numbers of information
10 belong to the group i, (N+1)th information is processed (i.e. encoded or decoded) while the generation probability P_i of the group i is regarded as M/N . This operation itself is performed on the group generation counting device 12 in the encoding apparatus (or on the group generation counting device 14 in the decoding apparatus).

15 [0027]

Next, algorithm of the grouping operation is explained. Incidentally, each of the DPCM device 21, the inverse DPCM device 34, the entropy encoding device 22, the entropy decoding device 32, the equal length encoding device 23, the equal length decoding device
20 33, code combining device 24 and the code dividing device 31 is constructed by the well-known technology , so that detailed descriptions about their insides are eliminated.

[0028]

Fig. 4 is a flowchart showing a process which is performed on
25 the grouping operating device and the group generation counting device in the example of the present invention. Firstly, at step S11

in Fig. 4, an initializing of the group is performed for performing the process. For example, the information source having the 256 values is divided into 9 units. In dividing, the dividing which is optimized for exponential distribution of 2.

5 [0029]

Fig. 5 shows an example of 9-units-dividing which is adopted when the initializing is performed. A portion where the value is near 0 is grouped by the relatively small width. A portion where the value is near 255 is grouped by the relatively large width.

10

[0030]

Next, at step S12, a division predicted coefficient S , which is used to assign the generation probability of the original group i to the divided groups $i1$ and $i2$ when the group i is divided, is set.

15 Moreover, a division judging threshold value ε , which is used for judge whether or not the dividing / connecting is performed, is set.

[0031]

After that, the data (here, the data after the DPCM is performed) is inputted (step S13), a belonged group to which the data belongs to and an inter-group position information of the data are identified (step S14), and each of the belonged group and the inter-group position information is binarized and outputted to the entropy encoding device 22 and the equal length encoding device 23 (step S15). The encoding is performed in each of the entropy
20 encoding device 22 and the equal length encoding device 23 on the basis of the output. The encoded data outputted from the entropy
25

encoding device 22 and the equal length encoding device 23 are transmitted after they are centralized-arranged on the code combining device 24.

[0032]

5 At step S16, the a generation-count (i.e. number of generation or generation frequency) is accumulated for each group and the generation probability P_i is calculated for each group. After that, a decrease (Gain) of the entropy which occurs when the group i having the largest generation probability P_i is divided into 2 units is
10 calculated (step S17). Moreover, with respect to the groups other than the above group i , an increase (Loss) of the entropy which occurs when two groups j and k (j and k is not equal to i) are connected is calculated (step S18). At this time, the groups j and k which realize the smallest loss L ($\min L$) are stored.

15 [0033]

 At step S19, it is judged whether or not the reconstruction (dividing / connecting) of the groups is performed, on the basis of the gain G and the loss L . Since the dividing / connecting is performed if $(G - \min L)$ is equal to or more than ϵ (i.e. $G - \min L \geq \epsilon$), a process
20 at step S20 is performed. Otherwise, a process at step S21 is performed.

[0034]

 In the case where the dividing / connecting is performed, new group is constructed (step S20). The group i at this time is equally
25 divided into 2 groups i_1 and i_2 , and the groups j and k at this time are connected. The generation probabilities of P_{iS} and $P_{i(1-S)}$ are

assigned to the divided groups i_1 and i_2 , respectively. After that, same processes are performed on the basis of the new generation probabilities. Moreover, the generation probability of $P_j + P_k$ is assigned to the connected group j_k .

5 [0035]

After that, it is judged whether or not the data which is to be encoded exists (step S21). If it exists, the process at step S13 is performed again. Namely, the data is inputted and the above-mentioned processes are performed again. If it does not exist,
10 the entropy encoding device 22 is informed about an end of the data.

[0036]

The processes performed on the grouping operating device and the group generation counting device in the encoding apparatus is explained above, however, same process logic is used to change the
15 grouping pattern in the decoding apparatus.

[0037]

A theoretical background about the group dividing process and the group connecting process is explained as follows.

[Theoretical background about the group dividing process]

20 Now, the case where one group G_M out of groups G_i ($i = 0, 1, \dots, n-1$) is equally divided into 2 groups is explained. This process makes the entropy decrease. The amount of the decrease is as follows. It is assumed that the generation probability of group G_M is P_M and the size of group G_M is M_M .

25 [0038]

The entropy H of the group G_M is indicated as $H = -P_M \log P_M +$

$P_M \log M_M$. With respect to the groups G_{M1} and G_{M2} which are newly generated by equally dividing the group G_M , it is assumed that the generation probabilities of the groups G_{M1} and G_{M2} become $S:(1-S)$, respectively. The entropy H_h after dividing is indicated as $H_h =$
 5 $-P_M S \log P_M S - P_M (1-S) \log P_M (1-S) + P_M S \log (M_M/2) + P_M (1-S) \log (M_M/2)$.
 The amount G of the decrease of the entropy due to the dividing process is indicated as $G = H - H_h = P_M ((1-S) \log (1-S) + S \log S + \log 2)$.
 And the range of G is indicated as $0 \leq G \leq P_M \log 2$.

[0039]

10 If S is equal to $1-S$, G becomes 0. If S is equal to 1, G becomes $P_M \log 2$. The gain (the decrease amount of the entropy) depends on a ratio between generation probabilities of 2 groups which is generated by equally dividing the original groups. It is preferable that the group G_i having the largest generation probability P_i is divided, in
 15 order to get the maximum gain.

[0040]

[Theoretical background about the group connecting process]

The case where new group G_c is generated by connecting the group G_j and the group G_k is explained. It is obviously considered
 20 that the entropy increases by connecting the groups. This increase can be regarded as the loss due to the connecting process. The connecting process which can connect 2 groups such that the loss is minimized is optimum process.

[0041]

25 The amount of the increase is as follows. The sum H of entropy of the group G_j and the entropy of the group G_k before

connecting is indicated as $H = -(P_j \log P_j + P_k \log P_k) + P_j \log M_j + P_k \log M_k$.
 The entropy H_c of the group G_c after connecting is indicated as $H_c = -(P_j + P_k) \log(P_j + P_k) + (P_j + 50P_k) \log(M_j + M_k)$.

[0042]

5 The loss (the increase of the entropy) L due to the connection process is indicated as $L = -P_j \log(1 + P_k/P_j) - P_k \log(1 + P_j/P_k) + P_j \log(1 + M_k/M_j) + P_k \log(1 + M_j/M_k)$. If P_k/P_j is equal to M_k/M_j , the loss L becomes 0.

[0043]

10 [Result of simulation]

 The result which is obtained by performing the simulation, in which the division predicted coefficient S is 0.3, the division judging threshold value ε is 0 and the groups j and k are limited the groups which are adjacent to each other, of the process in Fig. 4 is explained
 15 as follows. Moreover, in order to easily calculate the loss L in performing the connecting process even on a micro processor or the like, calculation of logarithm out of the calculation of the loss is approximated by Maclaurin expansion as follows.

[0044]

20 $\text{Log}(1+x) \doteq x - x^2/2 + x^3/3 - x^4/4$

 If x can be represented as power-of-two sum, the calculation of the gain G and the loss L can be performed by a shift operation (shift process) and an add / subtract operation (add / subtract process).

[0045]

25 In the example, a SIDBA standard image (GIRL, MOON, AERIAL, COUPLE) and a CCITT standard image which are

quantized by 8 bits are used as the information source which is the target. The grouping of each level plane and the dividing into 9 groups is performed. Fig. 5 shows the aspect of the grouping in the initial state. Moreover, as shown in Fig. 6, the DPCM in which an upper pixel is used as a reference pixel is performed. An arithmetic encoding method is used as the entropy encoding method (incidentally, an insert of a stuff bit is eliminated for simplicity). In encoding, Markov modeling which is conditioned by dividing difference of the reference pixel which is located on upper side into 5 states is performed.

[0046]

As a comparison example, a result of the encoding without performing the level plane connection, a result of the encoding with using fixed connection method which performs the level plane connection same as JPEG-SPATIAL method, and a result of the encoding with using a bit plane method are obtained.

[0047]

(a) an example of the encoding of the natural image

An used modeling is as follows.

(i) Preparation : A sample image (256×256 pixels, 8 bits / sample) is inputted into an predicted encoding device, and a predicted error value which is obtained from the output of the predicted encoding device is used as arithmetic encoded target.

[0048]

(ii) Conditioning : The conditioning is performed by dividing into 5 states as shown in Fig. 7(A).

(iii) Update of Pattern : The updating of the plane connection pattern is performed dependently for each conditioning state such that each state occurs by 128 times.

[0049]

5 The result which is obtained by performing the simulation of the encoding of the above natural image is shown in Fig. 8(A). As is clear from the result, in the case of the natural image, the code length in each method has substantially same value. However, in the case of not performing the plane connection (i.e. performing pure
10 level plane developing), quantity of states which need to be calculated in entropy encoding is 256×5 states. On the other hands, in the case of not performing the grouping, quantity of states which need to be calculated in entropy encoding is only 9×5 states, which means that the process of the encoding is greatly simplified.

15 [0050]

(b) an example of the encoding of the texture image

An used modeling is as follows.

(i) Preparation : A sample image (840×1188 pixels, 8 bits / sample) is inputted into an predicted encoding device, and a
20 predicted error value which is obtained from the output of the predicted encoding device is used as arithmetic encoded target.

[0048]

(ii) Conditioning : The conditioning is performed by dividing into 5 states as shown in Fig. 7(A).

25 (iii) Update of Pattern : The updating of the plane connection pattern is performed dependently for each conditioning state such

that each state occurs by 128 times.

[0052]

The result which is obtained by performing the simulation of the encoding of the above texture image is shown in Fig. 8(B).

5 Considering the result of the simulation of the encoding of the texture image, unlike in the case of the natural image, distribution is different from the exponential distribution. For this reason, the code length in ③ the fixed connection method and ④ the bit plane method is more than twice the code length in ② the method without
10 performing the plane connection.

[0053]

However, in ① the method using present invention, since the optimum level dividing is properly performed with respect to an arbitrary probability distribution, the increase of the code length is
15 suppressed up to only several %, compared to the method without performing the plane connection. This result proves that the method using the present invention properly performs as it originally intended.

[0054]

20 Generally, when the encoding of the image is performed, the statistic properties are several and do not necessarily conform the exponential distribution. For this reason, it is considered that the method using the present invention is effective method in order to solve such the problem.

25 [0055]

(c) an example of the encoding of the texture image,

without the predicted encoding device

An used modeling is as follows.

(i) Preparation : The predicted encoding is not performed.

Therefore, image data itself is the arithmetic encoded target.

5 [0056]

(ii) Conditioning : The conditioning is performed by dividing into 5 states as shown in Fig. 7(B).

(iii) Update of Pattern : The updating of the plane connection pattern is performed dependently for each conditioning state such
10 that each state occurs by 128 times.

[0057]

In the above mentioned simulation (a), the predicted encoding device is prepared before the arithmetic encoding device. Here, the code length in the case of not using the predicted encoding device is
15 considered. The result which is obtained by performing the simulation of the encoding of the natural image in the case of not using the predicted encoding device is shown in Fig. 9.

[0058]

By not using (i.e. eliminating) the predicted encoding device,
20 it is possible to estimate (assess) how effective the method using the present invention functions with respect to the statistic property of the image itself. In this case, it can be said that the estimation is performed with respect to the statistic property which is slightly different from the statistic property in the above-mentioned example.
25 As is clear from the result shown in Fig. 9, the result of the method using the present invention is superior to the result of the fixed

connection method and the result of the bit plane method. Of course, it is preferable to use the predicted encoding device in order to seek the improvement of the efficiency of the encoding. However, even if the predicted encoding device is not used (is eliminated) in order to
5 simplify the construction of the encoding device, the arithmetic encoding device itself using the method of the present invention can achieve some degree of the effect.

[0059]

[EFFECT OF INVENTION]

10 As is clear from the above description and the result of the simulation, according to the present invention, it is possible to realize the efficiency of the encoding, which is same as the efficiency of the encoding which is realized in converting the multiple value into binary with using the level plane method, with respect to the
15 images having both properties such as the natural image and the texture image, even if the SPATIAL encoding is performed. Despite this, it is possible to greatly reduce the quantity of the states which are the target for the entropy encoding from 256 states to 9 states, in the case of the above example. This means that the process of the
20 encoding is greatly simplified (thereby, process speed is greatly improved). Especially, in the case of performing the entropy encoding on the basis of multiple Markov modeling, the effect is remarkable, and it can contribute the realization of the more practical encoding device which does not depend on the information
25 source which is the encoded target.

[Brief Description of Drawings]

[FIG. 1]

FIGs. 1 are a principle block diagrams of the present invention;

[FIG. 2]

5 FIG. 2 is a block diagram of an encoding apparatus in the example of the present invention;

[FIG. 3]

FIG. 3 is a block diagram of an decoding apparatus in the example of the present invention;

10 [FIG. 4]

FIG. 4 a flowchart showing a process which is performed on the grouping operating device and the group generation counting device in the example of the present invention;

[FIG. 5]

15 Fig. 5 shows an example of 9-units-dividing which is adopted when the initializing is performed;

[FIG. 6]

Fig. 6 shows an example of a reference pixel and the encoded pixel;

20 [FIG. 7]

Figs. 7 show the variety of the conditioning state used in the simulation;

[FIG. 8]

25 Figs. 8 show an example of the simulation for comparing the method using the present invention with the other method;

[FIG. 9]

Fig. 9 shows an example of the simulation for comparing the method using the present invention with the other method;

[FIG. 10]

Figs. 10 explain an example of the inter-level plane
5 connection.

[FIG. 11]

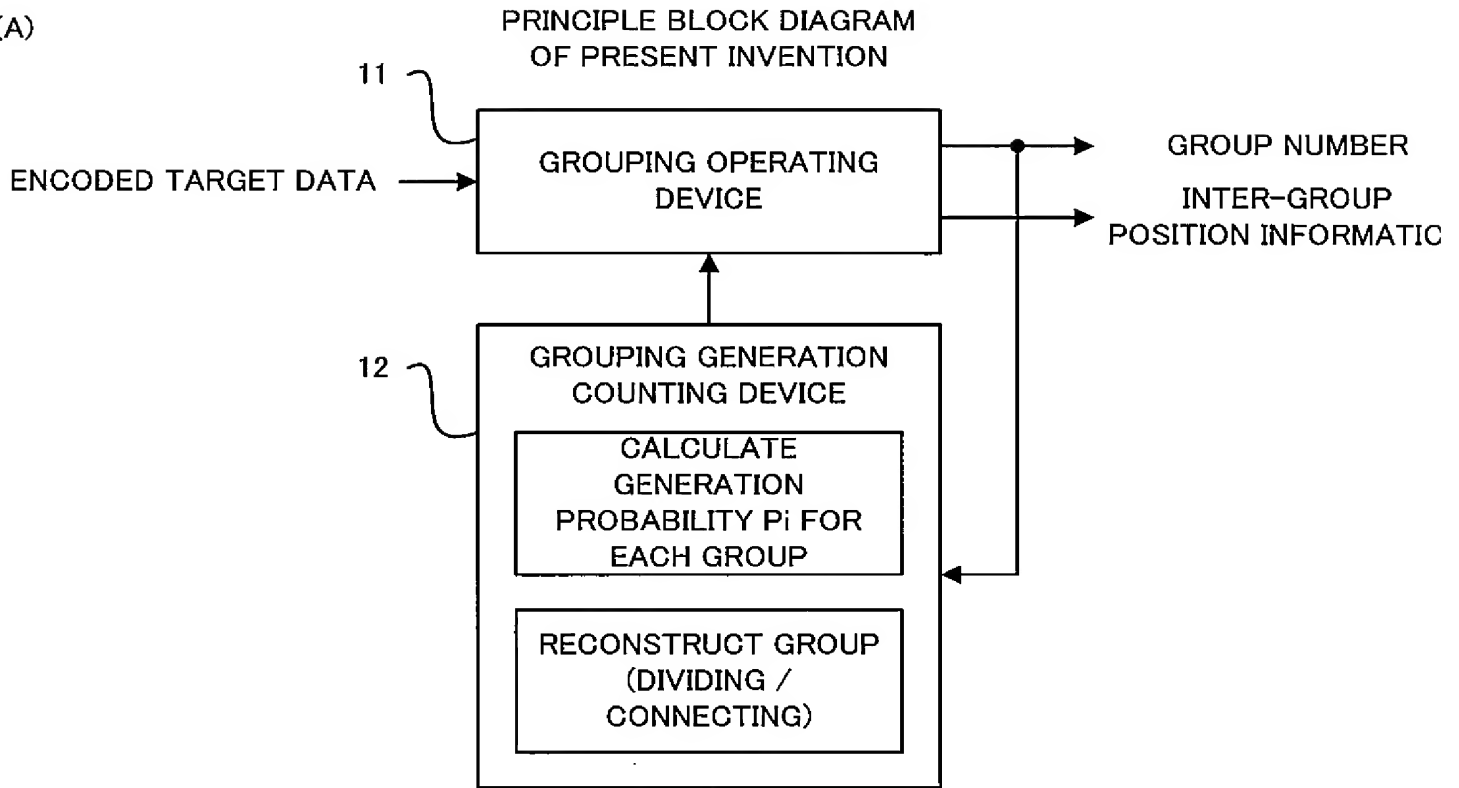
Figs. 11 explain a statistic property of the information source.

[Description of the reference]

- 11 grouping operating device
- 10 12 group generation counting device
- 13 de-grouping operating device
- 14 group generation counting device

FIG. 1

(A)



(B)

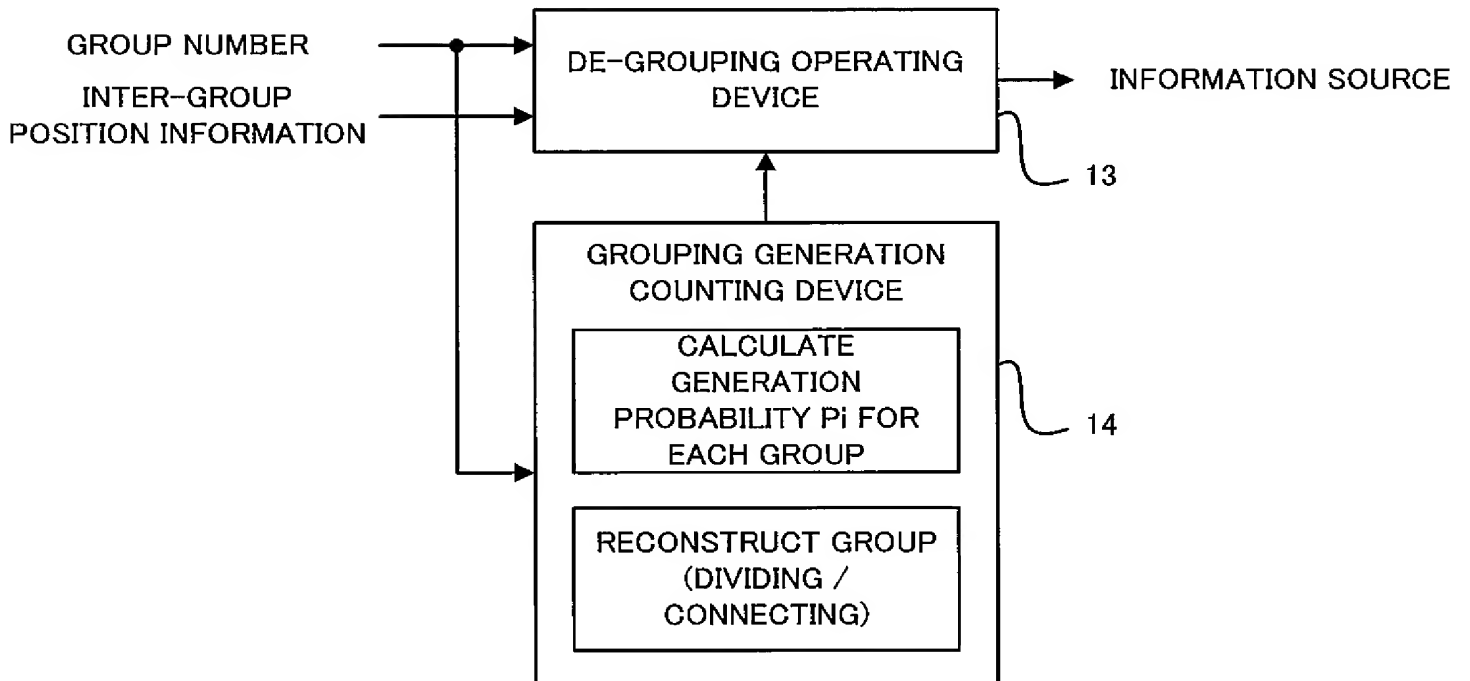


FIG. 2

BLOCK DIAGRAM OF ENCODING APPARATUS

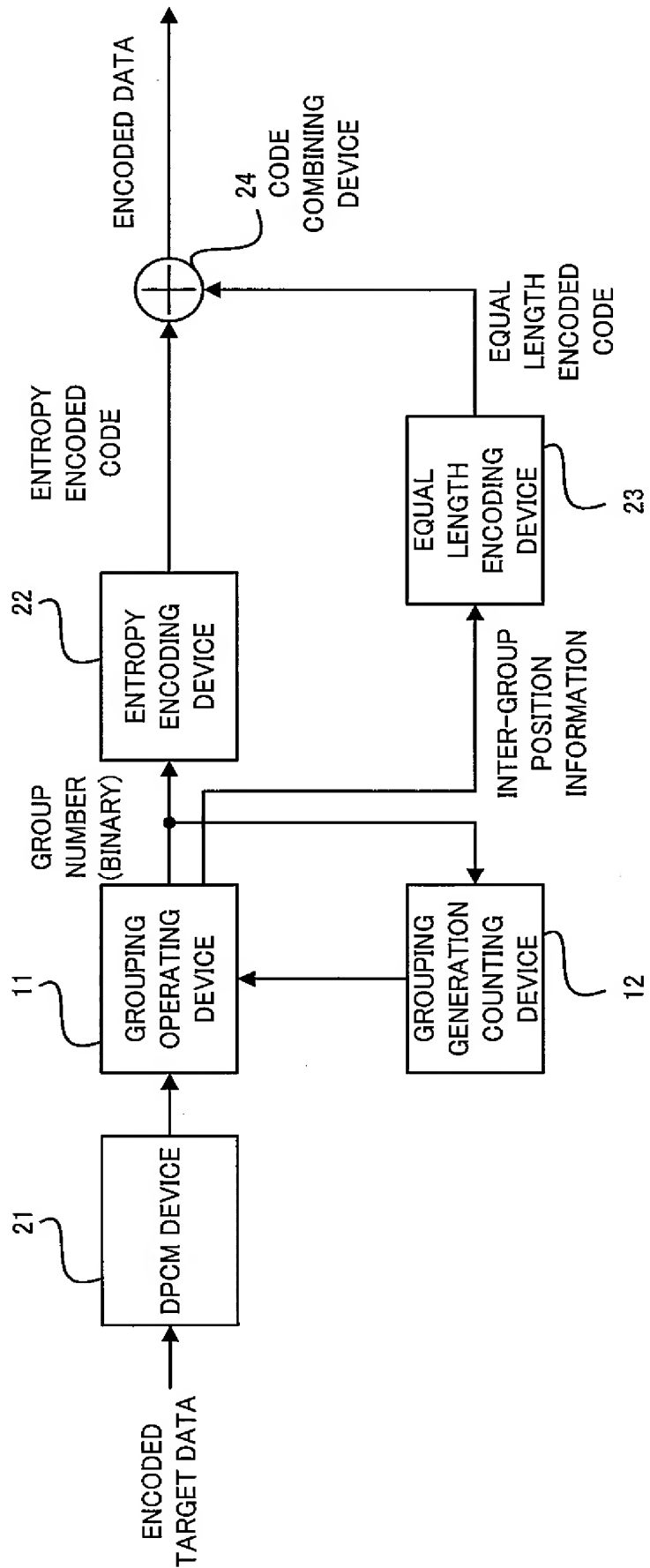


FIG. 3

BLOCK DIAGRAM OF DECODING APPARATUS

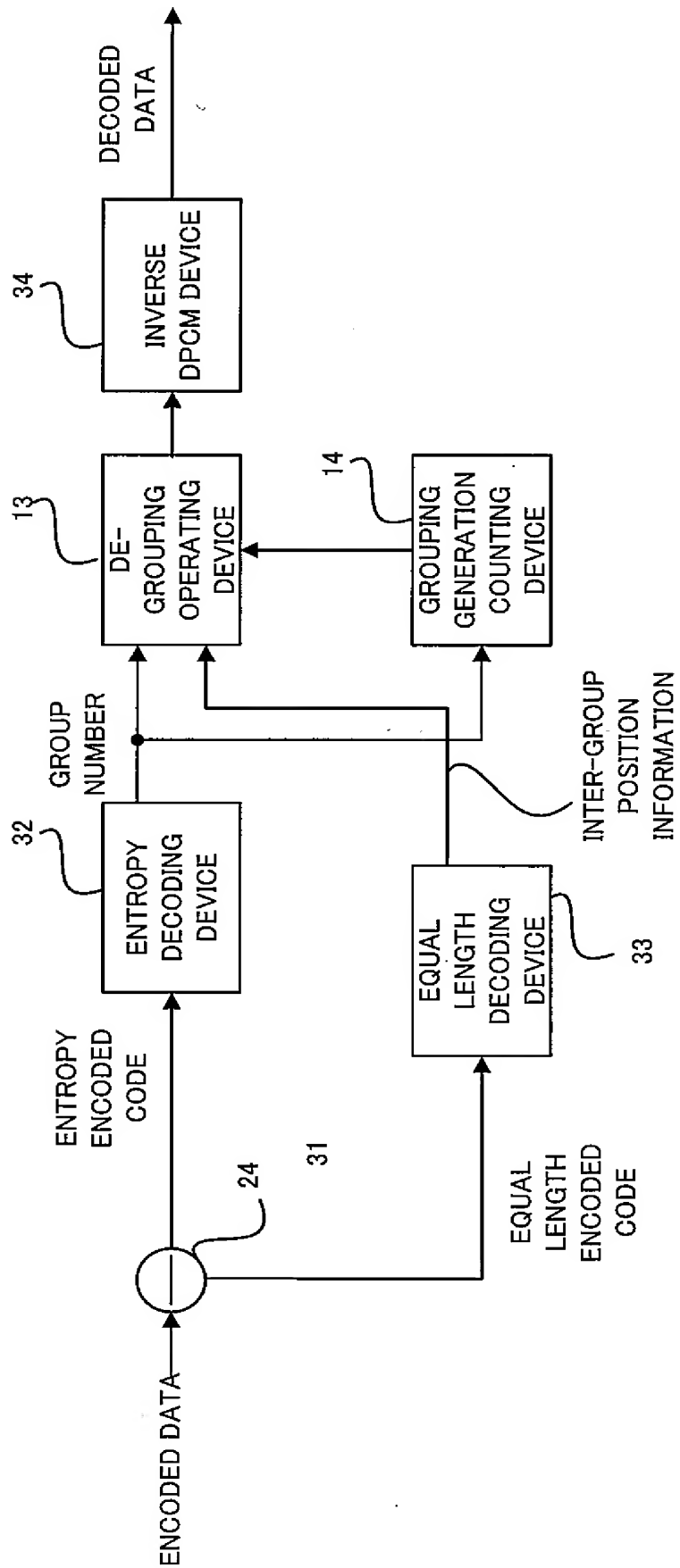


FIG. 4

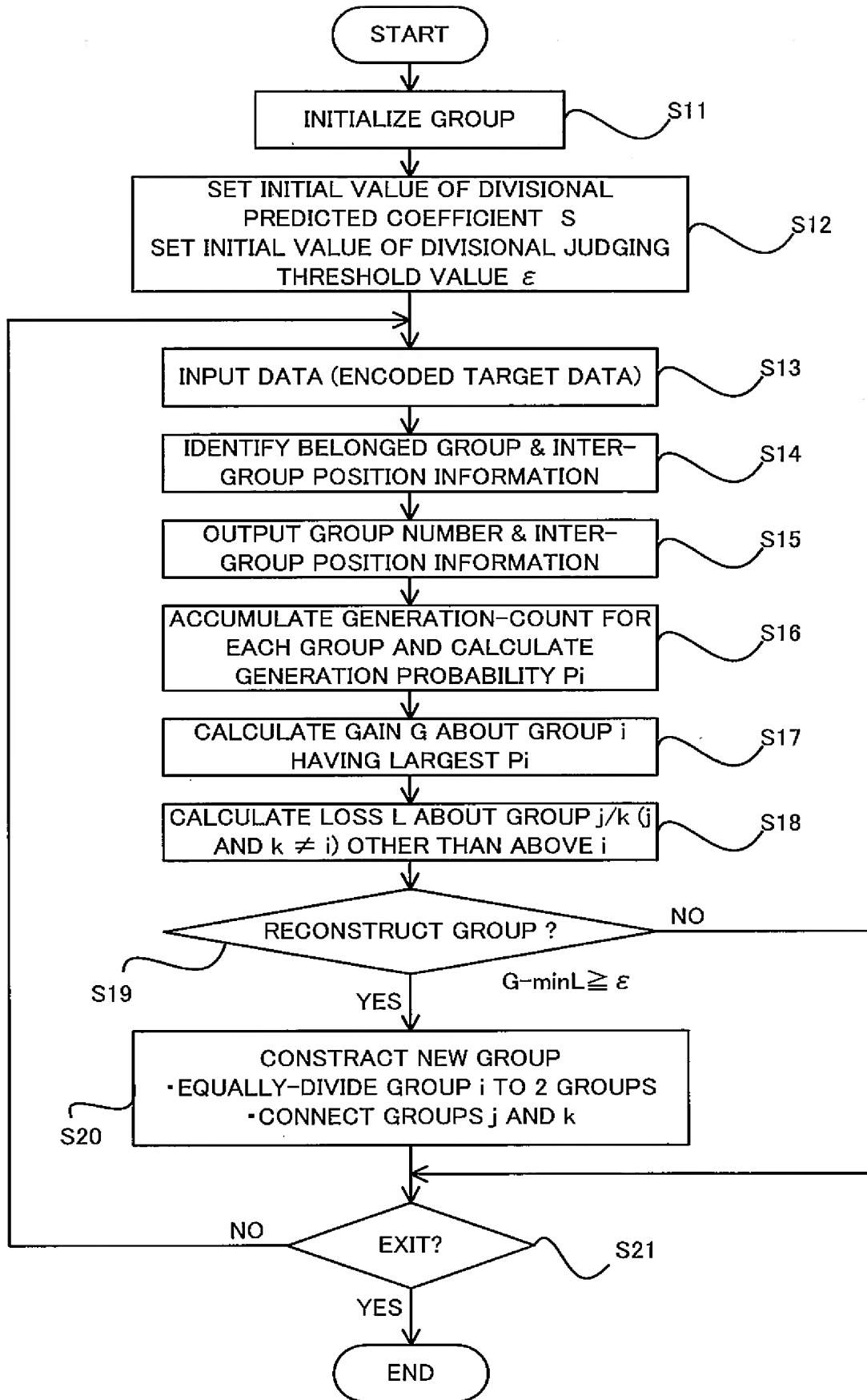


FIG. 5

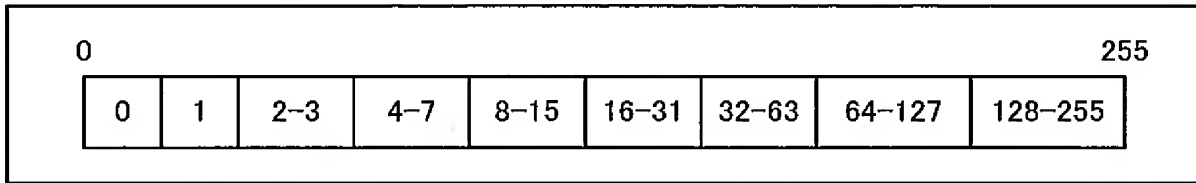


FIG. 6

REFERENCE PIXEL AND ENCODED PIXEL

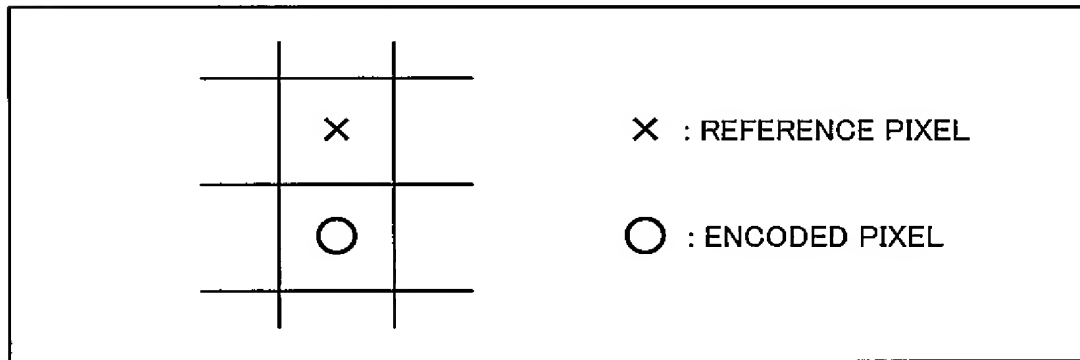


FIG. 7

CONDITIONS STATE

STATE NUMBER	VALUE e OF REFERENCE PIXEL
5	$0 \leq e < 51$
3	$51 \leq e < 102$
1	$102 \leq e < 153$
2	$153 \leq e < 204$
4	$204 \leq e < 255$

(A)

STATE NUMBER	VALUE e OF REFERENCE PIXEL
5	$-255 \leq e < -18$
3	$-16 \leq e < -4$
1	$-4 \leq e < 4$
2	$4 \leq e < 16$
4	$16 \leq e < 255$

(B)

FIG. 8

(A) ENCODING OF NATURAL IMAGE

METHOD \ IMAGE	GIRL	MOON	AERIAL	COUPLE
①PRESENT INVENTION	322,640 bit (4.92 b/p)	359,926 bit (5.49 b/p)	398,124 bit (6.07 b/p)	292,776 bit (4.47 b/p)
②WITHOUT PLANE CONNECTION	320,775 bit (4.89 b/p)	358,516 bit (5.47 b/p)	395,260 bit (6.03 b/p)	290,853 bit (4.44 b/p)
③FIXED CONNECTION METHOD (JPEG SPATIAL METHOD)	322,304 bit (4.92 b/p)	359,845 bit (5.49 b/p)	396,125 bit (6.04 b/p)	292,591 bit (4.46 b/p)
④BIT PLANE METHOD	330,023 bit (5.03 b/p)	361,509 bit (5.52 b/p)	398,666 bit (6.08 b/p)	304,627 bit (4.65 b/p)

(B) ENCODING OF TEXTURE IMAGE

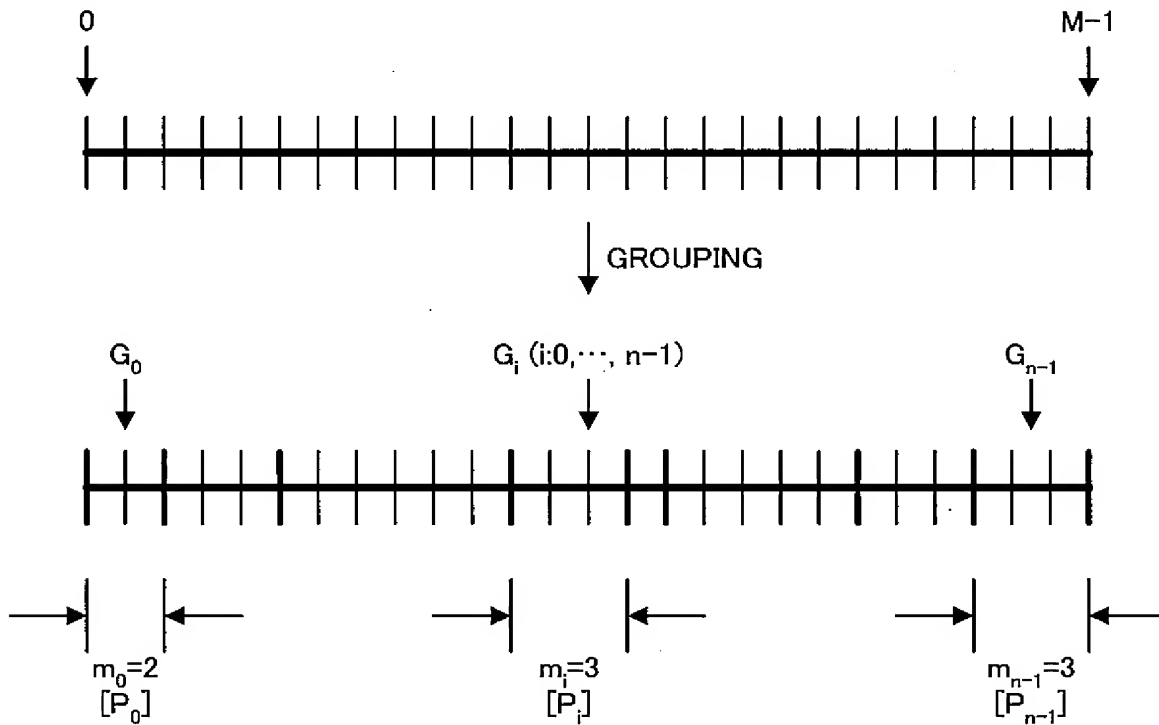
METHOD \ IMAGE	CCITT No.1	CCITT No.2	CCITT No.5	CCITT No.8
①PRESENT INVENTION	139,225 bit (0.14 b/p)	83,859 bit (0.08 b/p)	214,671 bit (0.22 b/p)	129,607 bit (0.13 b/p)
②WITHOUT PLANE CONNECTION	134,002 bit (0.13 b/p)	82,564 bit (0.08 b/p)	206,456 bit (0.21 b/p)	127,683 bit (0.13 b/p)
③FIXED CONNECTION METHOD (JPEG SPATIAL METHOD)	261,182 bit (0.28 b/p)	162,623 bit (0.16 b/p)	505,703 bit (0.51 b/p)	282,729 bit (0.28 b/p)
④BIT PLANE METHOD	957,712 bit (0.96 b/p)	573,727 bit (0.57 b/p)	1,498,171 bit (1.50 b/p)	914,268 bit (0.92 b/p)

FIG. 9

IN CASE OF NOT USING PREDICTED ENCODING DEVICE

METHOD \ IMAGE	GIRL	MOON	AERIAL	COUPLE
①PRESENT INVENTION	138,678 bit (0.14 b/p)	220,658 bit (0.22 b/p)	409,153 bit (6.24 b/p)	438,723 bit (6.69 b/p)
②WITHOUT PLANE CONNECTION	128,117 bit (0.13 b/p)	204,984 bit (0.21 b/p)	351,097 bit (5.56 b/p)	436,625 bit (6.66 b/p)
③FIXED CONNECTION METHOD (JPEG SPATIAL METHOD)	379,446 bit (0.38 b/p)	721,133 bit (0.72 b/p)	433,557 bit (6.62 b/p)	467,881 bit (7.14 b/p)
④BIT PLANE METHOD	968,852 bit (0.97 b/p)	1,580,557 bit (1.58 b/p)	450,413 bit (6.87 b/p)	481,468 bit (7.35 b/p)

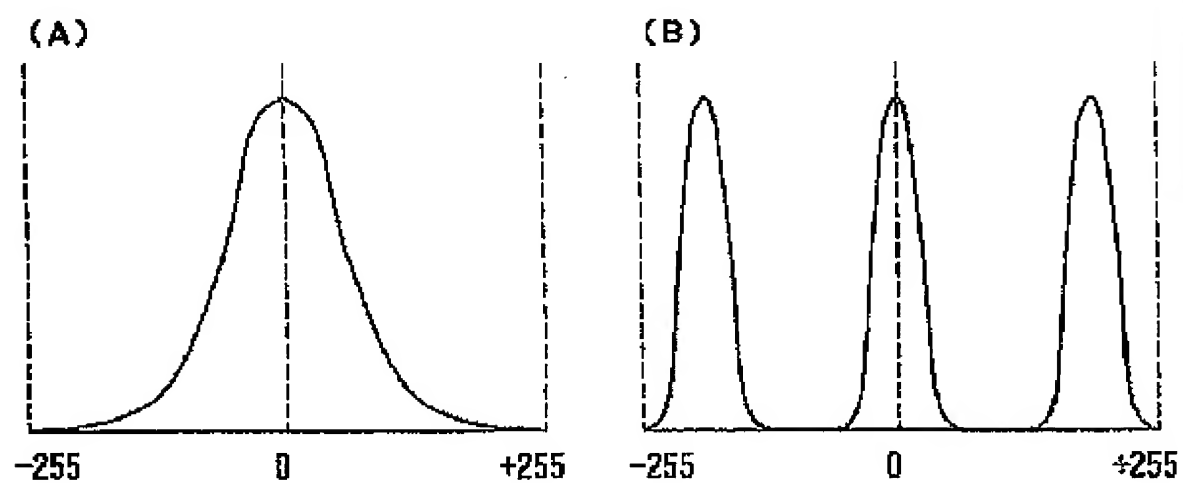
FIG. 10



G_i : GROUP NUMBER
 m_i : SIZE OF GROUP
 P_i : GENERATION PROBABILITY OF GROUP

FIG. 11

STATISTIC PROPERTY OF INFORMATION SOURCE



[DPCM, 8BIT QUANTIZATION]